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Laser-assisted Atom Probe Tomography and the Nanoscale Analysis of Geological Materials

DAVID W. SAXEY, DENIS FOUGEROUSE, WILLIAM D. A. RICKARD AND STEVEN M. REDDY

Curtin University

Atom probe tomography (APT) is a powerful analytical technique that enables three-dimensional elemental and isotopic characterization at sub-nanometre resolution across the entire periodic table. Originally developed for materials science and semiconductor applications, APT has recently gained traction in geosciences, offering unprecedented insights into nanoscale geochemical processes.

The key advancement in atom probe instrumentation allowing routine analysis of geological samples has been the commercial development of laser-assisted APT hardware. In this mode, pico- or femto-second laser pulses are focussed on a specimen, initiating the field-evaporation of ions and providing a time base for time-of-flight mass spectrometry. More recently, the use of shorter laser wavelengths, into the deep UV, have allowed a larger range of mineral types to be analysed.

Unlike similar mass spectrometry techniques, atom probe tomography also provides spatial information within the volume of analysis down to nanometer resolution. These hardware advances have thereby driven geochemical and geochronological research toward higher spatial resolution, allowing the characterization of elemental and isotopic reservoirs at smaller scales. As element interactions at the nanoscale fundamentally control geological transformations, achieving nanometer resolution in mineral analysis has provided significant opportunities to deepen our understanding of geochemical and geochronological phenomena. Furthermore, APT data often complement analyses obtained at higher length-scales, leading to multi-scale and correlative analytical workflows that enhance the interpretation of geological processes.

Recent atom probe studies on minerals have demonstrated the technique’s ability to address fundamental geological questions. The continued application of APT in the geosciences will involve further development and integration with complementary microscopy techniques for improved data quality and interpretation. This presentation provides an overview of APT, covering the instrumentation, data acquisition, and several cutting-edge examples of nanoscale chemical and isotopic analysis achieved with this technique.